Time Series Analysis of a Binary Gas-Solid Conical Fluidized Bed Using Radioactive Particle Tracking (RPT) Technique Data

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Highlights

- Time series analysis of Geldart's B and D particles trajectories in a Gas-solid fluidized bed
- Kolmogorov entropy and correlation dimension are calculated for individual particles
- Mixing index are found at different axial locations for both particles

1. Introduction

Gas-solid binary conical fluidized beds are used for many industrial operations such as drying, granulation, polymerization etc. However, most of the conical fluidized bed studies reveal about their overall performance in terms of overall pressure drop, minimum fluidization velocity prediction and global mixing and segregation characteristics [1, 2]. Literature data on gas-solids fluidized bed unfold their hydrodynamics as chaotic [3]. The solids motion is mainly responsible for this chaotic hydrodynamics and hence, it may also be the characteristic of conical gas-solids fluidized bed. Further, mixing and segregation behavior of such beds largely depends on their local hydrodynamics. Therefore, understanding the chaotic hydrodynamics of gas-solid binary conical fluidized bed will contribute for developing better design, operation and scale-up strategies. The chaotic hydrodynamics of conical fluidized bed can be experimentally found through time series analysis of a characteristic variable (pressure, solid trajectories, solid velocity etc.) [4].

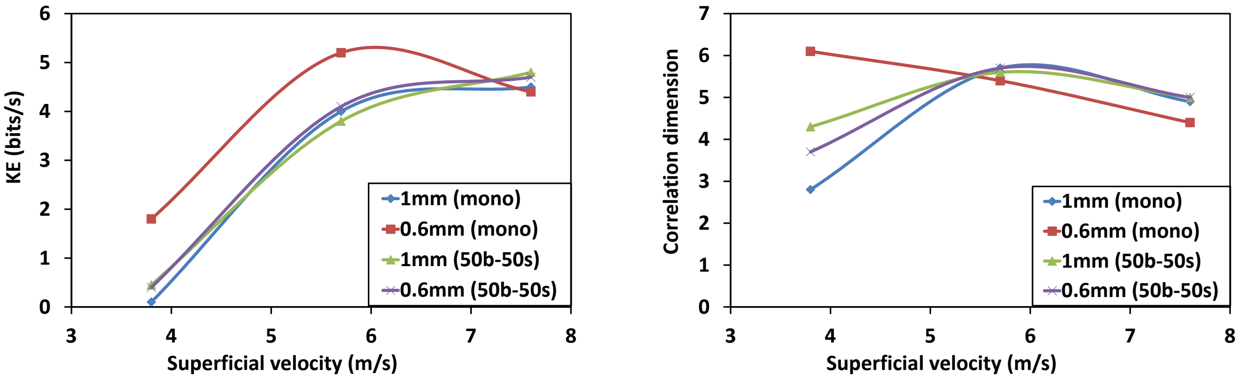
In current work, time series analysis of fluctuating velocities and Lagrangian solid particle track, representing the two solid particles of the examined gas-solid binary conical fluidized bed, is performed to reveal its hydrodynamics and mixing and segregation behavior. Radioactive particle tracking (RPT) technique is used to track the Lagrangian position of the particle and to calculate the fluctuating velocity from it. Experiments are performed for different bed composition and gas velocities. Rescaled Range (RS) Analysis, Eddy Diffusivity, Quality of Mixedness (QM) Index, and the Kolmogorov entropy and correlation dimension of the trajectory attractors are calculated for each condition.

2. Methods

In current work, radioactive particle tracking (RPT) technique is used for experimental investigation of gas-solid conical fluidized bed. In RPT, a radioactive tracer emitting gamma radiation is used to track the motion of solids in the bed. The tracer holds similar characteristics as of the remaining particles in the bed. During experiments, photons emitted by the tracer particle are recorded by a series of scintillation detectors placed strategically around the bed [5]. Total 12 scintillation detectors are used to track the motion of the tracer particle. Glass beads doped with Sc-46 are used as tracer particles. The conical fluidized bed used to carry out the experiments is of 0.05 m bottom diameter and 0.2 m top diameter with a tapering of 5.4^0. The particles used are glass beads of 0.6 and 1 mm mean diameter with 2500 kg/m^3 density, which falls in Group B and Group D particle respectively, as per Geldart's classification. Compressed air is used as the gas phase. The fluidized bed is operated at three velocities, i.e., 3.8 m/s, 5.7 m/s and 7.6 m/s which are 2, 3 and 4 times the minimum fluidization velocity (U_{mf}) of 1 mm particle. The bed composition was maintained as 0:100, 50:50, 75:25, 25:75 and 100:0 by mass for binary mixture of 1 mm and 0.6 mm particle, respectively. The total amount of solid used for all the experiment is kept constant, i.e., 1.36 kg. While using binary mixtures, individual particles are tracked for each set of experiments. The Lagrangian positions of the tracer particles are reconstructed by using photon count time series data. Thereafter, other parameters like instantaneous, mean, fluctuating and root-mean-square (rms) velocities, kinetic energy of fluctuations, stress etc., are calculated by suitable post processing [5]. Further, Hurst exponent, solid diffusivities, quality of mixedness index and the Kolmogorov entropy and correlation dimension of the trajectory attractors are calculated using time series analysis of fluctuating velocities and Lagrangian particle positions, to understand the mixing and chaotic behavior of the fluidized bed for each set of data.

3. Results and discussion

Figure 1 (a) and (b) show, respectively, the influence of the gas velocity on the Kolmogorov entropy (KE) and Correlation dimension (CD), calculated from the track of the 1 mm (big-b) and 0.6 mm (small-s) tracers. Results of the monosized beds of both particles, and of the binary bed of 50% mass composition are compared. Kolmogorov entropy indicates chaotic behavior for all the experimental conditions examined. Differences in chaotic behavior are marked for low gas velocities and become almost negligible when the U/U_{mf} ratio is high. The monosized fluidized bed of 0.6 mm particles shows a higher degree of chaotic behavior than the mono 1 mm bed, likely because the 0.6 mm bed is operated at higher U/U_{mf} ratio compared to the 1 mm bed. For the binary beds, the KE and CD calculated from the 0.6 mm or 1 mm tracer tracks are similar, indicating that in the mixture the 0.6 mm particles transfer some energy to the 1 mm particles. For very high velocity, the KE and CD determined for the four presented conditions are similar. The influence of the operating conditions on the chaotic behavior and mixedness and segregation parameters for monosized, 50% and other bed compositions will be presented in the full manuscript.



(a) (b)

Figure 1. Kolmogorov entropy and Correlation dimension of different composition with superficial velocity

4. Conclusions

In current work, the hydrodynamics of monosized and binary gas-solid conical fluidized bed is experimentally investigated by using RPT data. Time series analysis of the tracer tracks is performed to characterize the chaotic fingerprint and the mixing and segregation features. Results are presented for mono and binary bed of same density and different size particles, for different operating velocities and bed compositions. It is found that the hydrodynamics of gas-solid conical bed is chaotic and that the degree of chaotic behavior depends on the gas velocity..

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Keywords
Conical fluidized bed; Radioactive particle tracking; Mixing and segregation, Time series analysis